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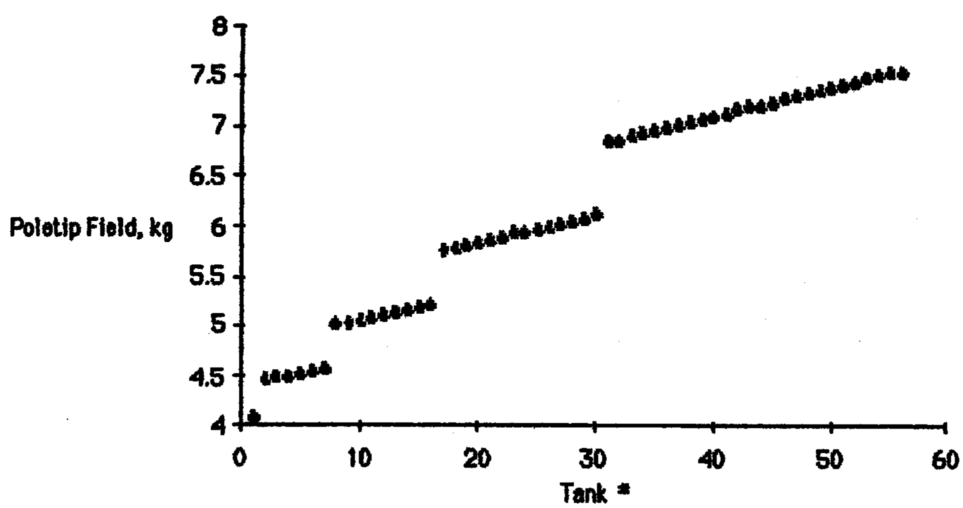
7/10/87

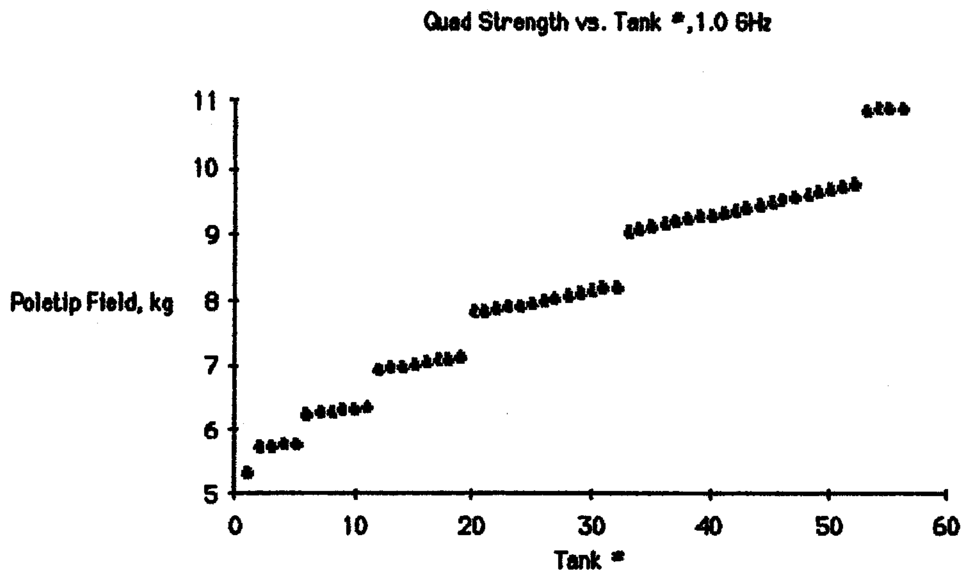
Effect of Operating Frequency on Linac Upgrade Performance

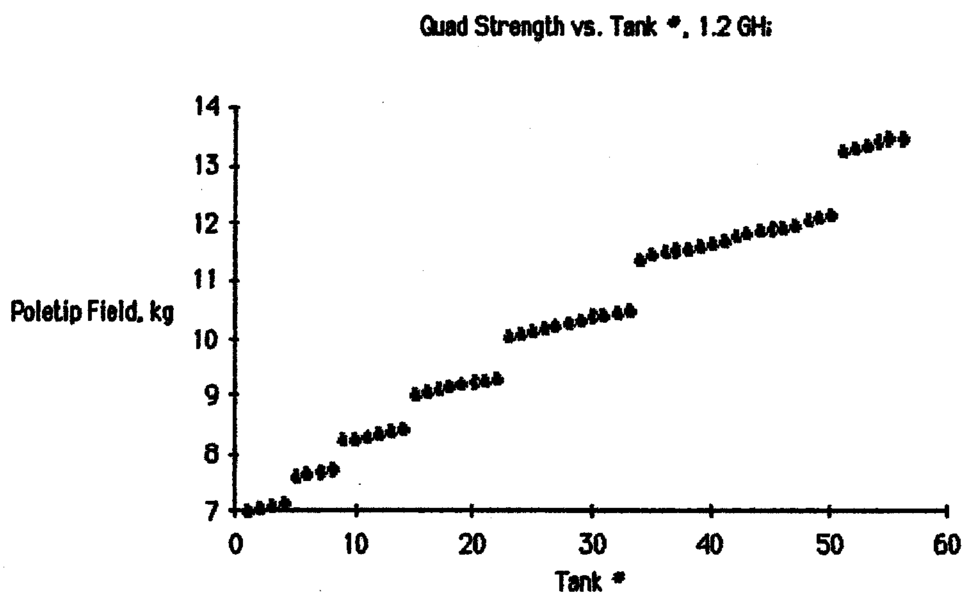
1) Transverse focussing requirements

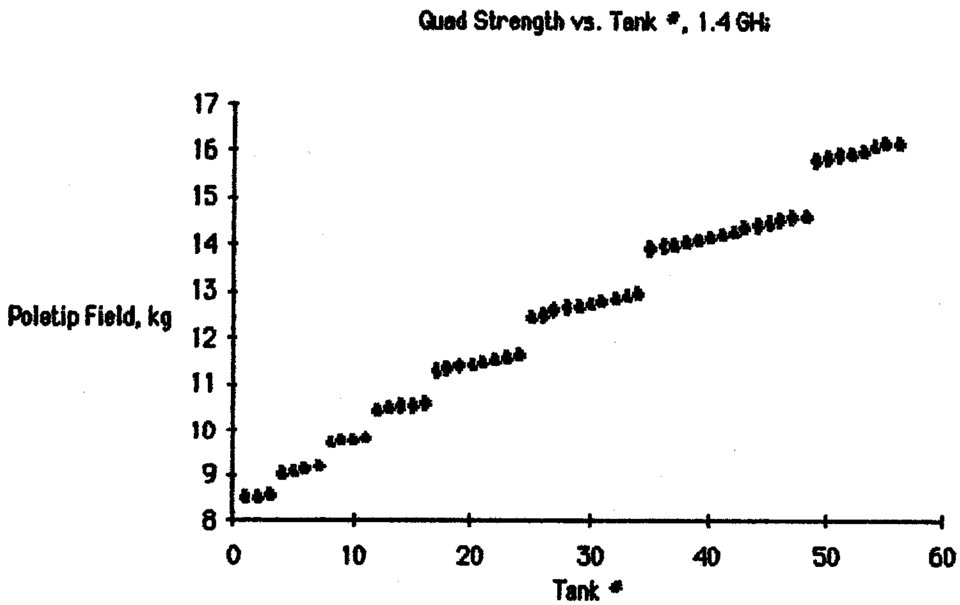
The RF defocussing at 805 MHz is about 10-20% of the quadrupole focussing and is proportional to frequency. At higher frequency, the cell length goes down, so there is less length for quadrupoles. This appears to place a firm limit at 1200-1400MHz without changing the cavity layout. The figures below show the required Poletip field assuming that each tank (about 2 m length) is matched to a 10MW power source, and that there is only one "bridge" or nonaccelerating cell per tank with a quadrupole of 4 cm. poletip diameter in it. (The other quad is between tanks.) The phase advance per FODO cell is set to be about $\pi/3$. Since the tanks are quantized in cell numbers, steps in quad strength occur where the number of cells/tank changes. It is clear that permanent magnet quads are only applicable at 800MHz unless we start putting more than one bridge (nonaccelerating) cell per tank. At 400 MeV, and 1200 MHz the lost length per $\beta\lambda/2$ cell is about 8.9 cm, or about 4.5% loss in average gradient; or a 9% increase in power to get the same average gradient. More work needs to be done to determine the number of additional cells per tank required for each frequency. (MacLachlan)

Quad Strength vs. Tank #,0.8 Ghz



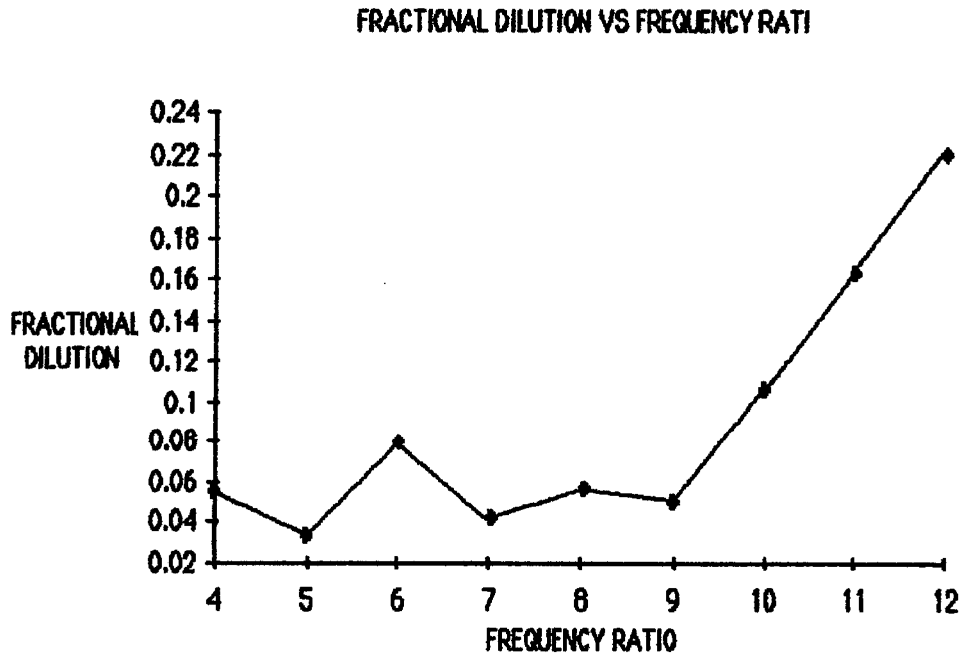

Quad Strength vs. Tank #,1.0 GHz
Poletip Field, kg
Tank #
11
10
9
8
7
6
5
0
10
20
30
40
50
60


Quad Strength vs. Tank #, 1.2 GHz
Poletip Field, kg
Tank #
14
13
12
11
10
9
8
7
0
10
20
30
40
50
60



2) Transverse matching; Alvarez to DAW or SCS
Should not change much as frequency is raised. (MacLachlan)

3) Longitudinal matching
At some point the nonlinearities in the RF waveform will make the rotator section inefficient, probably when the phase width of the bunch from the Alvarez section exceeds ±45-60deg. in the rotator section. If we are willing to use an intermediate frequency for the rotator, we can probably overcome this limitation. If we are not, then we are limited to about 1.6 gHz (see figure below).



(Mills)

4) Shunt Impedance

The question is whether we can maintain adequate shunt impedance as the beam hole diameter d is kept constant while the wavelength λ is lowered. As is seen in the table below, this can be done to some extent by raising the peak field to regain the transit time factor by reducing the tip radius, but keeping the ratio of peak field to Kilpatric field approximately constant. There is also an implied relationship between the power available from a power source, the shunt impedance, the cavity length and the transverse focussing which must be worked out for each frequency considered.

With a constant bore tube diameter of 3 cm, and a constant accelerating field of 7MV/m

Frequency(MHz)	805	1006.25	1006.25	1207.5	1207.5	1408.75	1408.75
ZT^2 MΩ/m	38.75	35.4	37.36	33.41	35.29	30.9	32.2
T (transit)	0.891	0.859	0.864	0.84	0.843	.826	.828
KE,MeV	116.5	116.5	116.5	116.5	116.5	116.5	116.5
Tip radius(cm)	0.41	0.41	0.3	0.3	0.21	.21	.16
Kilpatric Ratio	1.6	1.3	1.6	1.3	1.6	1.3	1.6
Kilpat. Field(MV/m)	26	28.7	28.7	31	31	33.3	33.3

(Moretti)

5) Intertank and Intratank Phase Stability
Is the required tank-tank phase stability easier or harder at higher frequency? At LAMPF,(805MHz) the phase is held to ±1°, and the amplitude to ±1%. In weakly coupled cells (SCS) of about 5%, the phase varies by 2.3° from drive point to end of tank. This is less a problem in strongly coupled cells (DAW) of 50%. (Young & Oleksiuk)

6) Space Charge
Both longitudinal and transverse space charge effects will be worse at higher frequency because the bunches are shorter. (Oleksiuk & MacLachlan))

7) Power System Cost: 100μsec pulse @ 15Hz

There is experience in RF power systems of this general type in the neighborhood of 1200 MHz, but not at exactly our required frequency. A project will be required to develop a klystron at this frequency, as at 800MHz. A comparison of development and unit costs provided by a potential vendor is presented in the table below.

Frequency	805	1207.5
Power MW	10	15
R&D Cost (First tube)	950k	433k
Cost/tube	160k	110k
Cost/magnet	25k	50k
Cost/socket(+shielding)	6k	7k

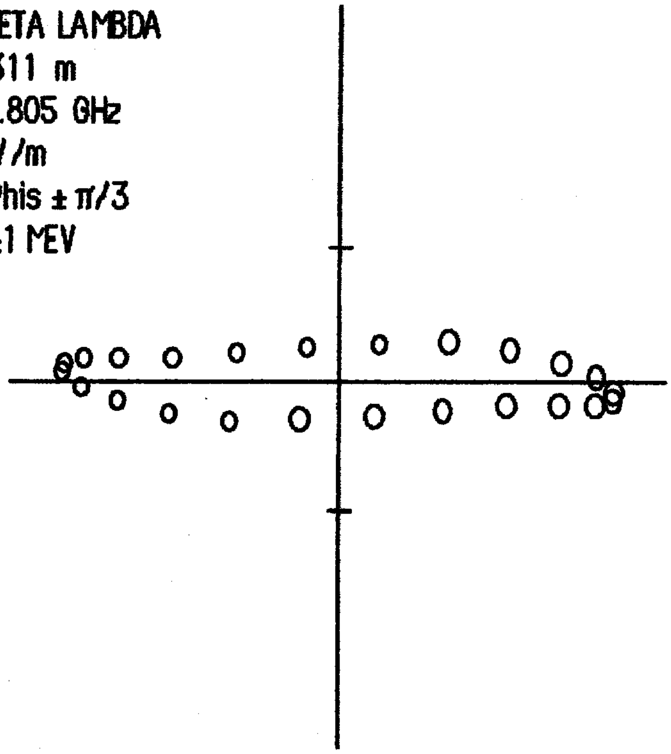
(Moretti)

8) Structure Costs
(Lee & Young)

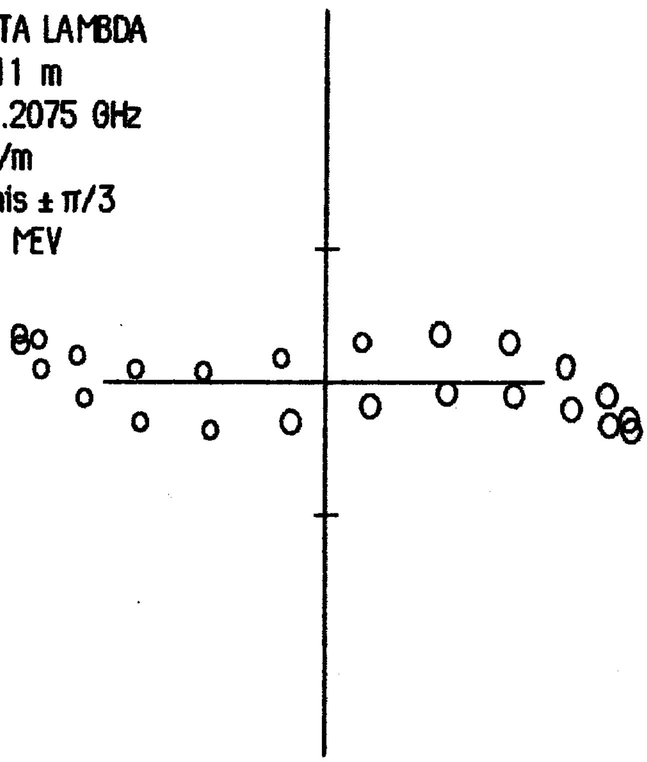
9) Debuncher

In order to obtain low momentum spread it is necessary to operate a debuncher in the Linac to Booster beam line. This is particularly true at the higher frequencies and higher fields. There is room available in the line after the chute, before MV2. This turns out to be slightly past the optimum distance for 805 MHz, and well past the optimum for 1207.5 MHz. This is shown in the figures below. The only alternative is to locate the debuncher cavity in the chute. the drift distance can be reduced from 27 m to about 20 m, as in the third figure. (Mills)

NCELL= 2 BETA LAMBDA
DIST= 27.5311 m
Frequency= .805 GHz
EFD= 4.3 MV/m
Horiz. line: Phis ± π/3
Vert. ticks ±1 MEV



NCELL= 3 BETA LAMBDA
DIST= 27.5311 m
Frequency= 1.2075 GHz
EFD= 3.3 MV/m
Horiz. line: Phis ± π/3
Vert. ticks ±1 MEV



NCELL= 3 BETA LAMBDA
DIST= 20.5311 m
Frequency= 1.2075 GHz
EFD= 4 MV/m
Horiz. line: Phis ± π/3
Vert. ticks ±1 MEV